APPENDIX C

NUMERICAL MODEL INVESTIGATION OF THE SAVANNAH RIVER ESTUARY

C-1. Introduction.

a. A description of the Savannah River estuary (Figure C-1) is given in Appendix B, paragraph B-8, of this EM and will not be repeated here.

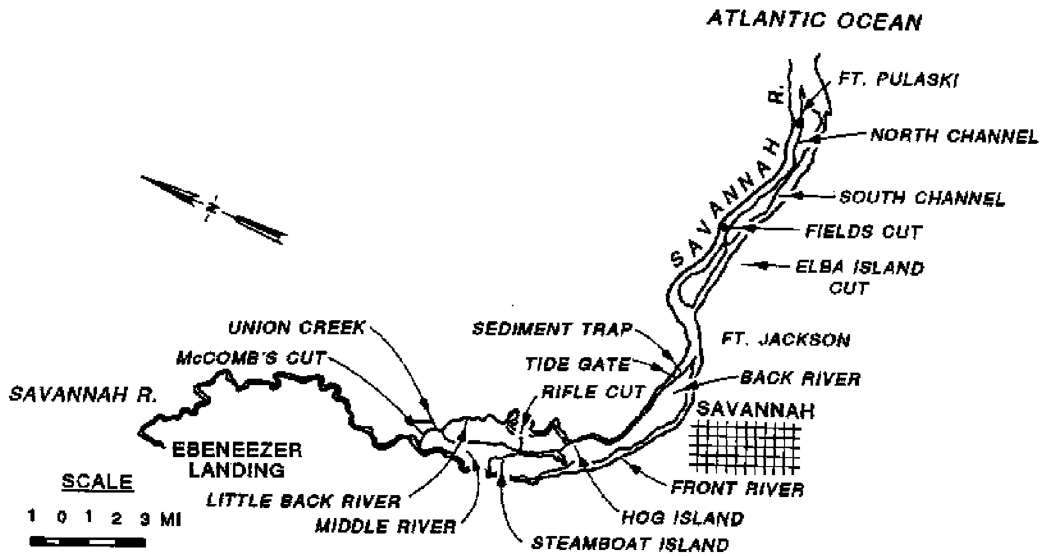


Figure C-1. Savannah River estuary

b. The objectives of the numerical modeling effort were threefold: to predict the impact of channel deepening and widening on salinity intrusion, on channel shoaling (maintenance dredging requirements), and on navigation safety along Front River.

c. To address the first two objectives, a laterally averaged finite difference model named LAEMSED was applied. To address the third objective a ship simulator study was conducted (Hewlett, Daggett, and Heltzel 1987). To provide the channel currents required to conduct the ship simulator study, a depth-averaged, finite element model called RMA-2V was used.

C-2. Salinity Intrusion and Shoaling Study--LAEMSED.

a. Numerical Grid. The modeled area extends along Front River from river mile 0.0 (10 miles downstream from Fort Pulaski) approximately 45 miles upstream to Ebeneezer Landing (river mile 44.7). Grid generation consisted of segmenting the Savannah River system into 16 distinct branches as listed in Table C-1 and shown in Figure C-2. The vertical grid spacing on each branch was 3.0 feet. A computational time step of 60 seconds was employed. The schematization of each branch is listed in Table C-2.

TABLE C-1

Branches of Savannah River

Branch	Location
1	Ebeneezer Landing through McComb's Cut along Little Back River to Front River
2	From McComb's Cut down Front River to 10 miles seaward of Fort Pulaski
3	Connection from Front River to Hog Island on Back River
4	Middle River
5	Steamboat Island Channel
6	South Channel from Front River to Ocean
7	Elba Island Cut
8	Marsh channel on Back River
9	Marsh channel on Back River
10	Marsh channel on Front River
11	Marsh channel on Little Back River
12	Marsh channel on Little Back River
13	Marsh channel on Front River
14	Rifle Cut
15	Marsh channel on Middle River
16	Union Creek

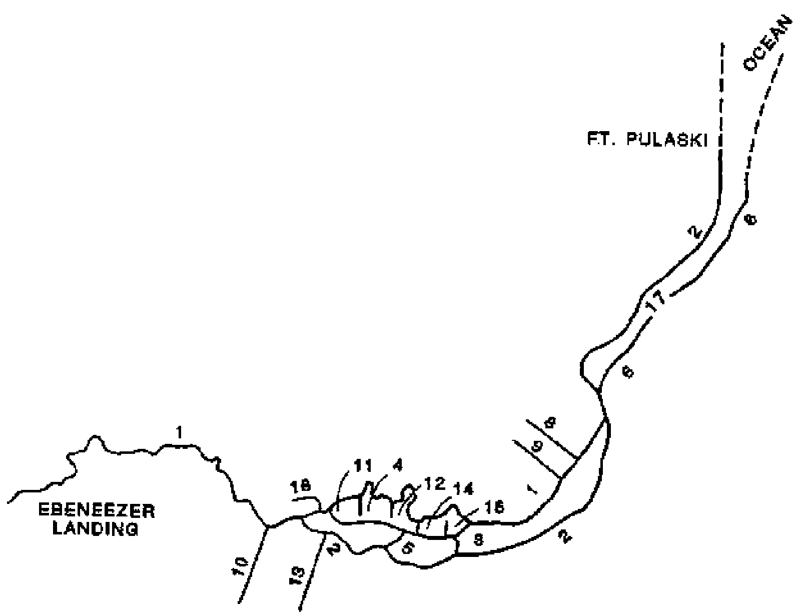


Figure C-2. LAEMSED branch locations

TABLE C-2

Schematization

Branch	Δx, m	No. of Δx's
1	1,074	55
2	1,610	36
3	1,000	4
4	1,006	8
5	386	6
6	1,610	19
7	468	3
8	4,000	4
9	4,000	4
10	2,500	4
11	4,000	4
12	4,000	4
13	4,000	4
14	200	4
15	4,000	4
16	1,000	4

Note: Δx = distance between nodes (computational points)

b. Boundary Conditions. Daily averaged freshwater inflows at Ebeneezer Landing and tides at Fort Pulaski were recorded for several days before and after the initiation of the 13-hour detailed field survey. Ten tidal cycles were used as a "start-up" period. Tidal data at Fort Pulaski were translated to the ocean boundaries of branches A and F which extended 10 miles into the ocean. A constant salinity of 33 parts per thousand was prescribed at these boundaries. In this application the sediment computations were turned off and thus no sediment boundary conditions were required.

c. Model Verification. To match observed tides, velocities, and salinities at interior locations, the Chezy roughness coefficient and off-channel storage were adjusted. Initial estimates of storage in particular reaches were determined from National Oceanic and Atmospheric Administration/National Ocean Survey (NOAA/NOS) nautical charts showing the limits of flooding. Values of the Chezy coefficient ranged from 60 metres per second in the navigation channel to 30 metres per second in Back and Middle Rivers.

d. Tide Gate Operation. The tide gate is a gravity-operated structure. Therefore, when the water level on the riverside exceeds that on the ocean side, LAEMSED initiates the closing of the gate. This is accomplished by decreasing the Chezy coefficient in the reach containing the gate by a factor of 10 over the next 10 time-steps (a period of 10 minutes). At the end of the tenth time-step, flow through the gate is completely stopped. This procedure reduces the initial shock to the computations caused by the closing of the gate. When the water level on the ocean side is greater than the riverside level, water is allowed to pass through the reach containing the gate in a normal fashion.

e. Results. Figures C-3 through C-5 show typical comparisons of computed and recorded tides, velocities, and salinities at Fort Jackson. As can be seen, excellent agreement of tidal ranges and phases as well as vertical distributions of velocities and salinities has been achieved.

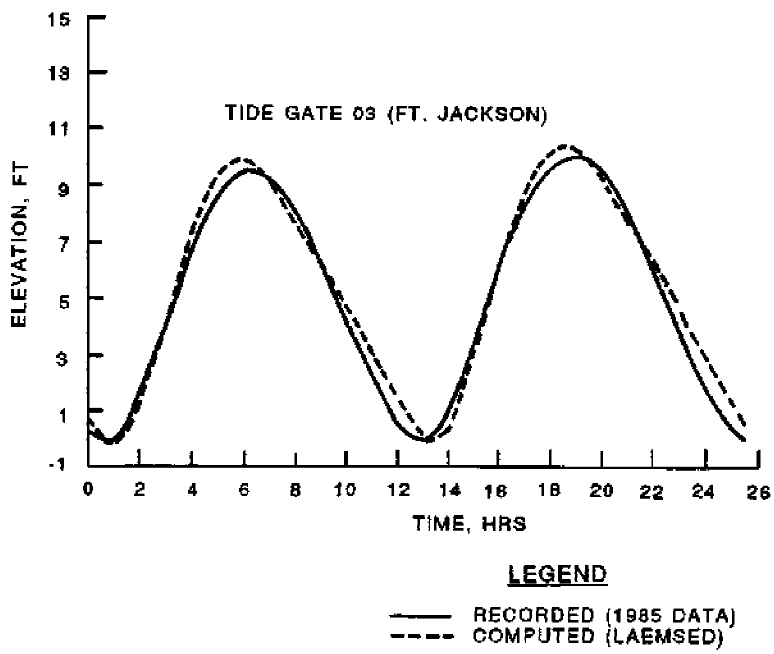


Figure C-3. Computed versus recorded 1985 tides at Fort Jackson

f. Sediment Verification. Adjustment of the model's critical shear stresses and erosion rate constants to reproduce shoaling rates was accomplished by running the model for the complete 28-day cycle of tides recorded at Fort Pulaski during the 1985 survey. Computed shoaling rates along Front River and in the sediment trap were then compared with estimates based upon dredging records from 1977 to 1980.

g. Boundary Conditions. The tidal record at Fort Pulaski was prescribed at the ocean boundaries with either a low (5,200 cubic feet per second), normal (8,400 cubic feet per second) or high (16,000 cubic feet per second) constant freshwater inflow prescribed at Ebeneezer Landing. Based on 1985 survey measurements, constant suspended sediment concentrations of 30 and 300 parts per million were specified as boundary conditions at Ebeneezer Landing and the ocean boundaries, respectively. The boundary condition on salinity was as previously discussed. The 30-part-per-million concentration was applied uniformly from surface to bottom at Ebeneezer Landing, and the

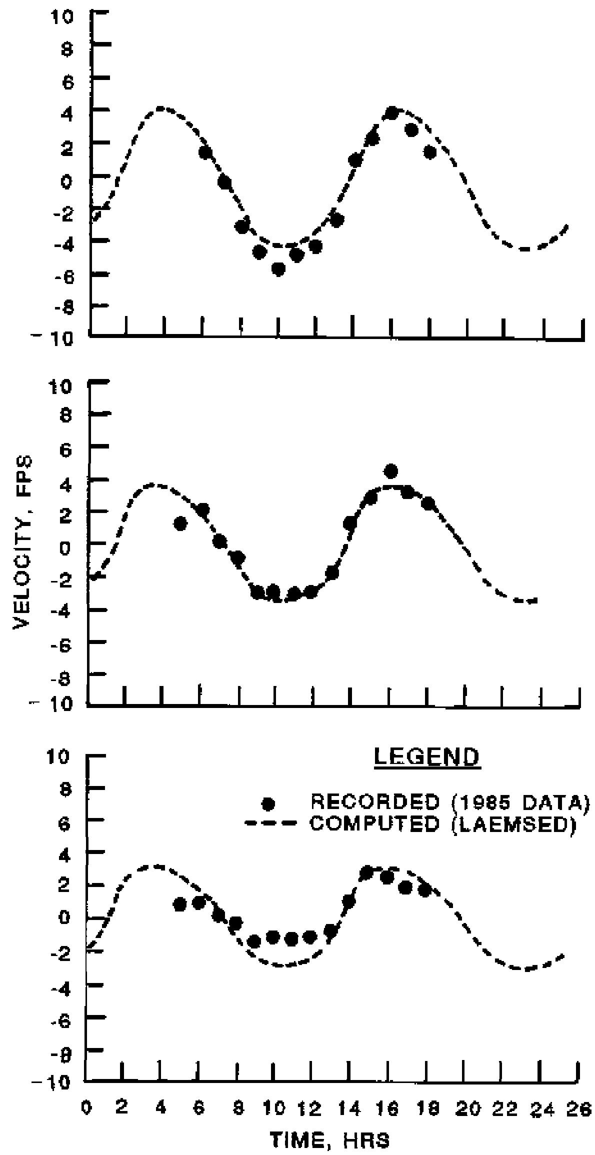


Figure C-4. Computed versus recorded 1985 velocities at Fort Jackson

300 parts per million uniformly from surface to bottom at the ocean boundary.

h. Bed Model. Shoaling problems in the Savannah Estuary result primarily from the deposition of fine-grained material. Thus the sediment was considered to be a clay. Initially, the channel bed was set to project depth in the navigation channels and to NOS chart depths elsewhere, with a spatially uniform concentration of suspended sediment of 30 parts per million in the water column. Only two layers were allowed in the bed model. The critical shear stress for erosion was set to be 0.6 Newton per square metre in the top

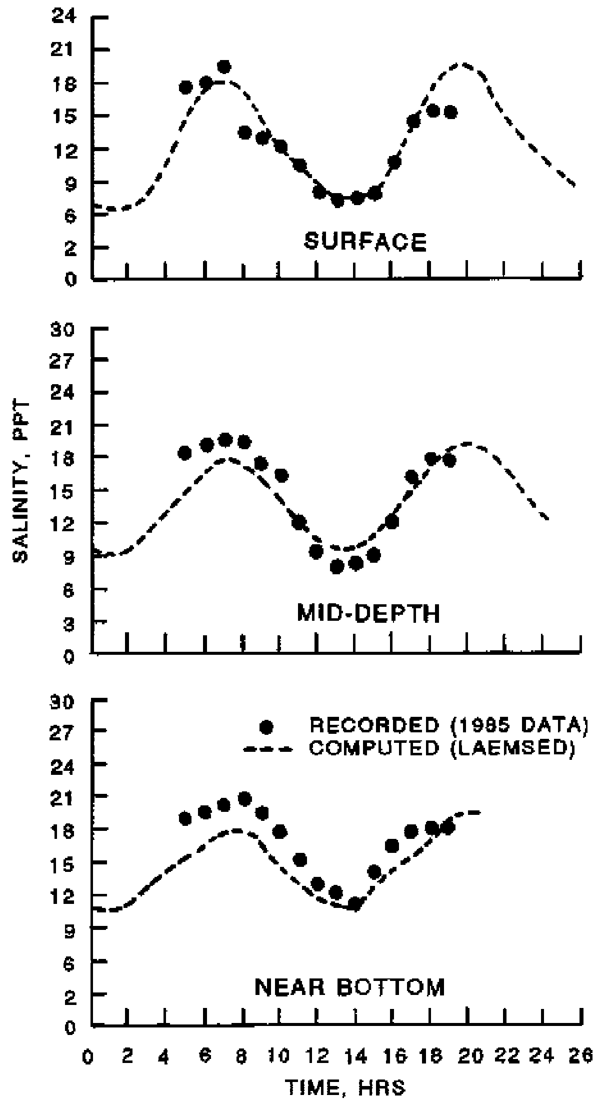


Figure C-5. Computed versus recorded
1985 salinities at Fort Jackson

layer and 1.0 Newton per square metre in the second layer. The thickness of the upper layer was set to be constant at 0.01 metre, whereas the bottom layer thickness was variable. The concentration of material in both layers was taken as 400 kilograms per cubic metre, yielding a bulk density of the bed of 1.25 grams per cubic centimetre.

i. Results. Figure C-6 compares computed infill rates determined from 1977-1980 dredging records. The computed values were determined first as an average over the 28-day cycle of tides and then extrapolated to provide yearly averages. Little difference in shoaling rates was computed for the different freshwater inflows. Those shown in Figure C-6 are for a normal freshwater inflow.

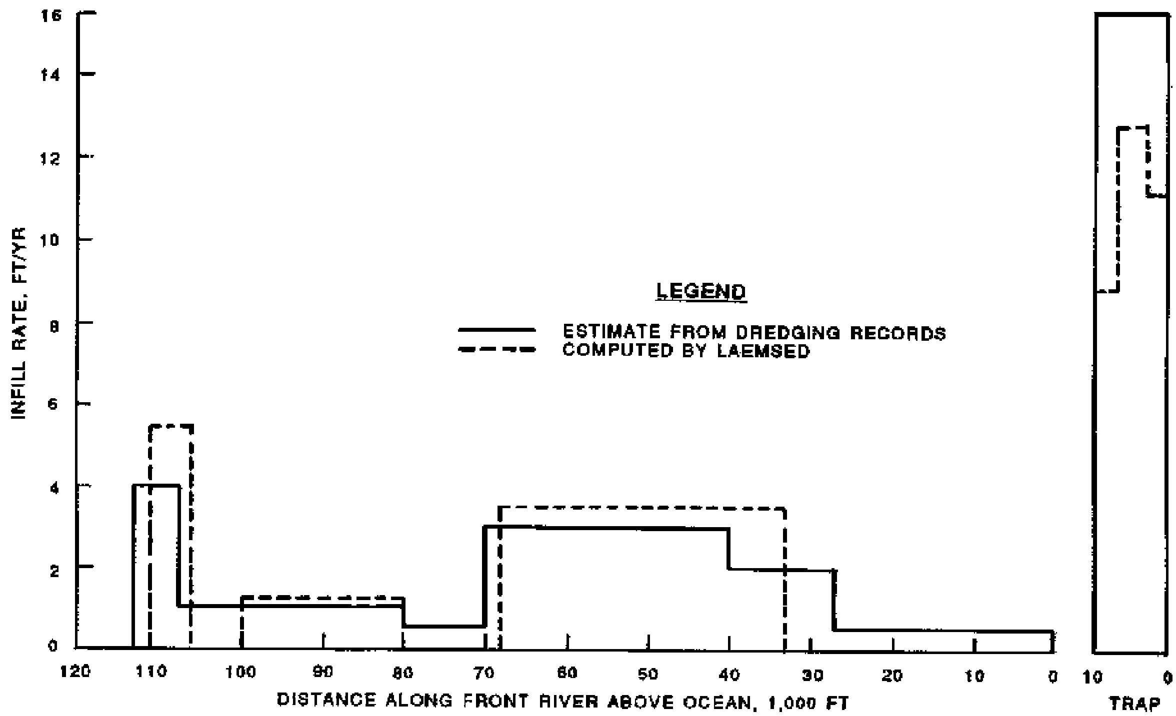


Figure C-6. Shoaling distribution in navigation channel

C-3. <u>Tidal Currents for Navigation Study--RMA-2V.</u>

a. Of all the data required to develop a detailed scenario for a navigation channel design study, obtaining the currents in the waterway for both the existing and proposed channels is extremely important yet difficult to obtain. Currents are typically the primary source of difficulty in maneuvering a ship in a restricted waterway. to obtain these values, a finite element model of the area of a portion of the Savannah River as shown in Figure C-7 was developed. This procedure is discussed in Thomas and McAnally (1985). The finite element mesh (Figure C-8) was refined to provide adequate detail across and along the river. The model bottom definition was derived from the latest available hydrographic survey (Hewlett, Daggett, and Heltzel 1987), which was modified to reflect dredging for the proposed planned channel.

b. For the model verification boundary conditions, the US Army Engineer Waterways Experiment Station conducted a field study in the Savannah estuary in April 1985 (see Appendix B for details). Tides, velocities, salinities, and suspended sediment concentrations were recorded at several locations along the estuary from the mouth to the upstream end of tidal intrusion. The tidal and velocity measurements in the vicinity of the numerical model mesh provided

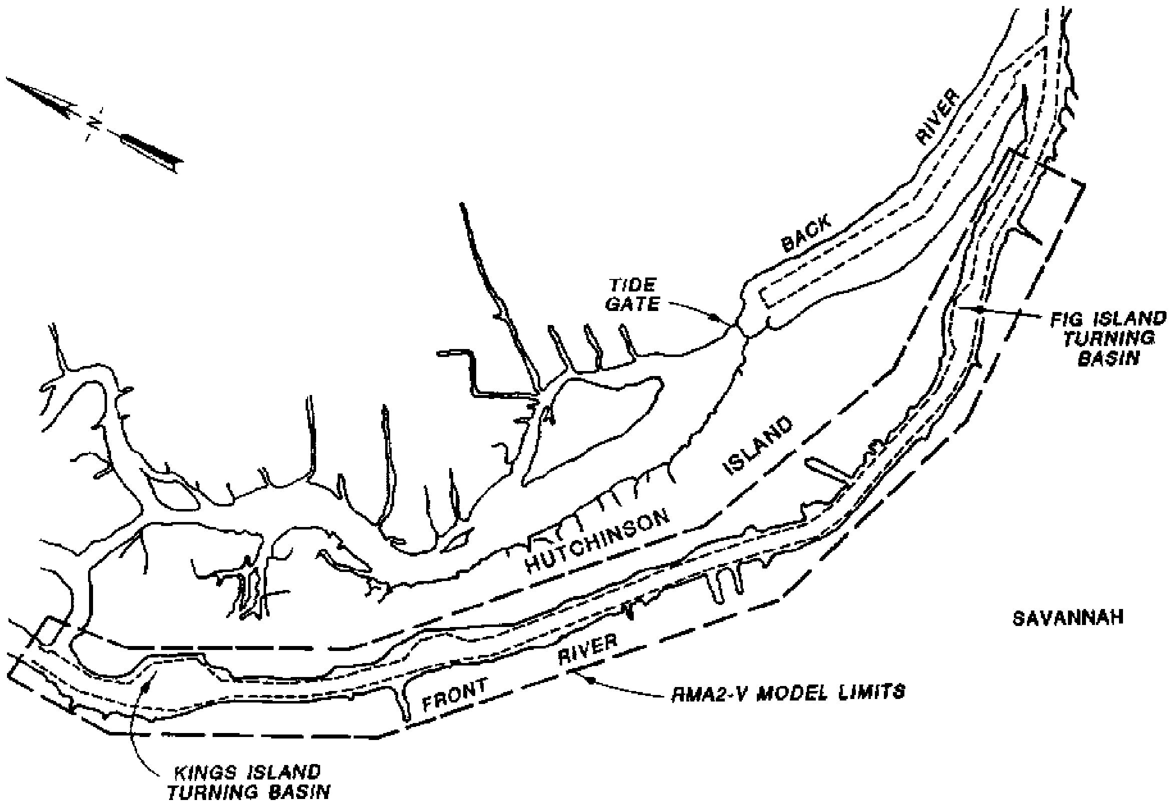


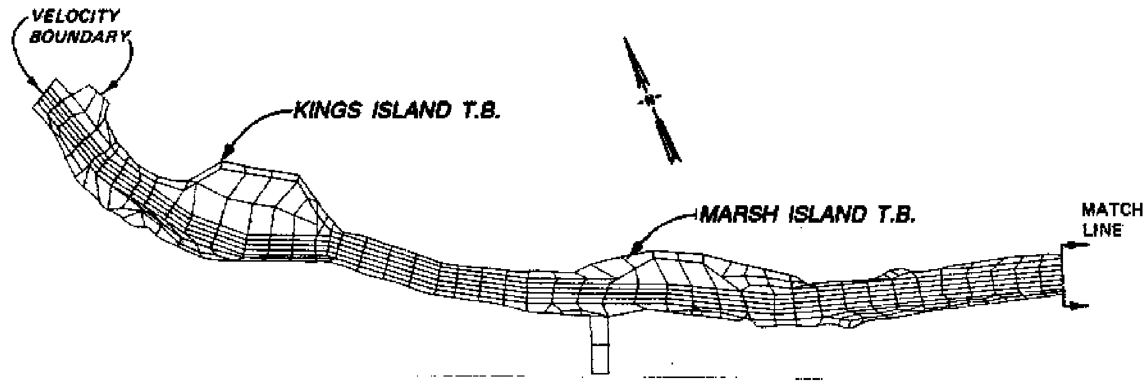
Figure C-7. Savannah Harbor

the data necessary to develop boundary conditions and to ensure that the model was reproducing tidal velocity conditions within the mesh in a reasonable manner necessary to run the numerical model for a complete tidal cycle.

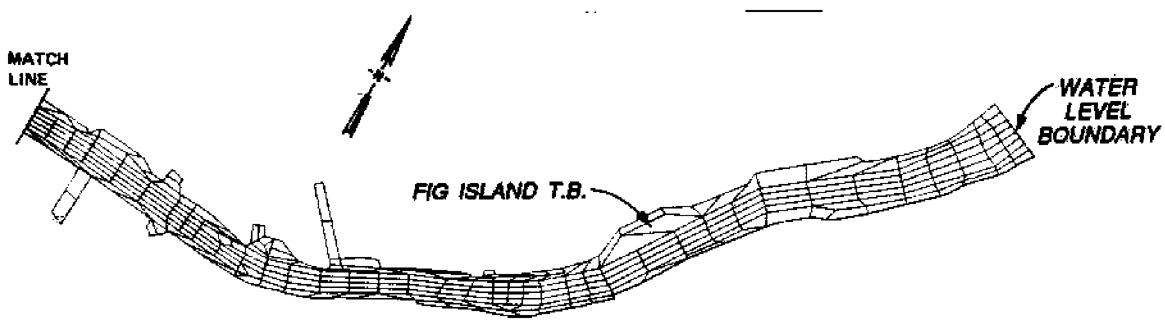
c. Prototype data and model results were compared at two different cross sections in the existing channel model. One of these cross sections was immediately downstream of the US Army Engineer District, Savannah, operations yard, and the other was upstream of the Talmadge Bridge at the location of the Diamond Construction Company's dock on the north bank, stations R-5 and R-6 in Figure C-9. Figure C-10 shows an example of the comparison of the field data and the numerical model results. As can be seen, agreement is close. An example plot of the current vectors from the finite element model is shown in Figure C-11.

C-4. <u>Typical Results from Deepening Study.</u>

a. Typical study results regarding the impact of channel enlargement on salinity intrusion predicted from the LAEMSED model are shown in Figure C-12. Typical sedimentation results, again predicted from the LAEMSED model, are given in Figure C-13.



a. Upper river section



b. Lower river section

Figure C-8. Existing channel and tidal basin RMA-2V grid

b. Typical results from the ship simulator study, which used the currents from the RMA-2V hydrodynamic model, are shown in Figure C-14.

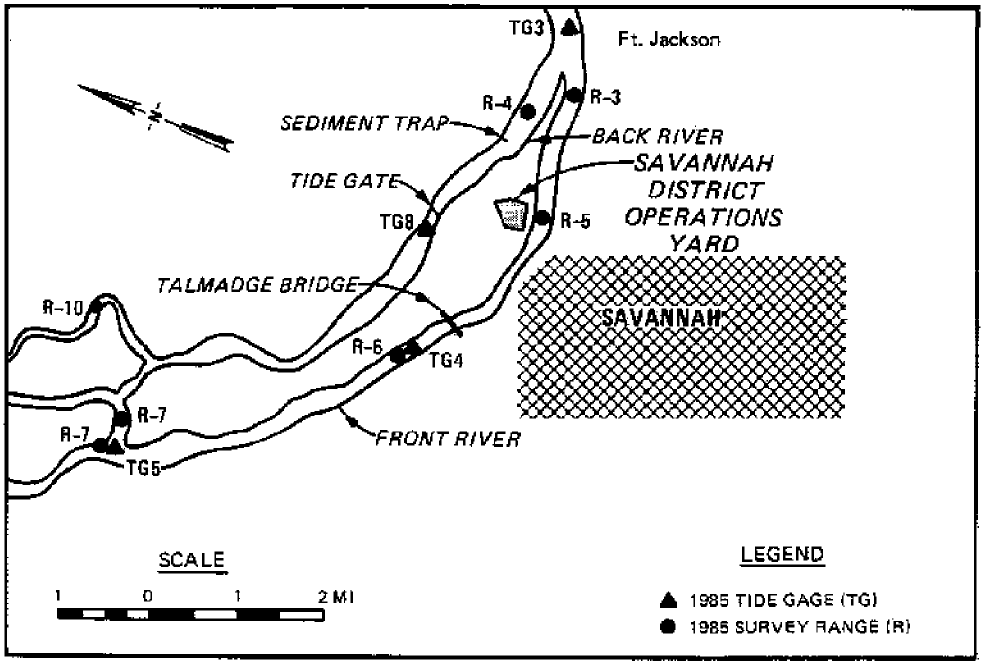


Figure C-9. Prototype measurement locations for Savannah Harbor ship simulation study

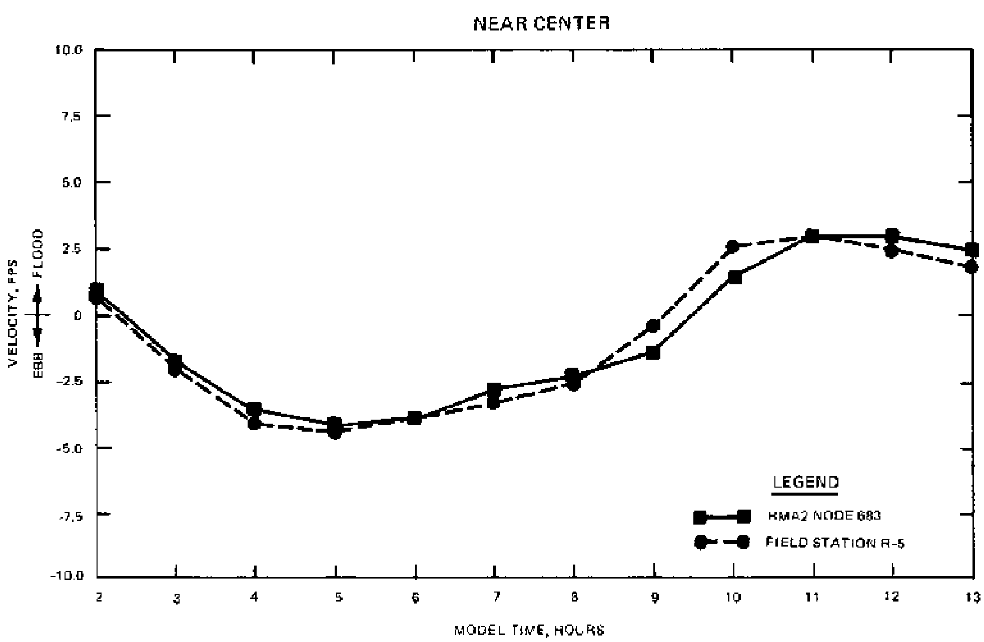


Figure C-10. Model-field velocity comparison at station R-5

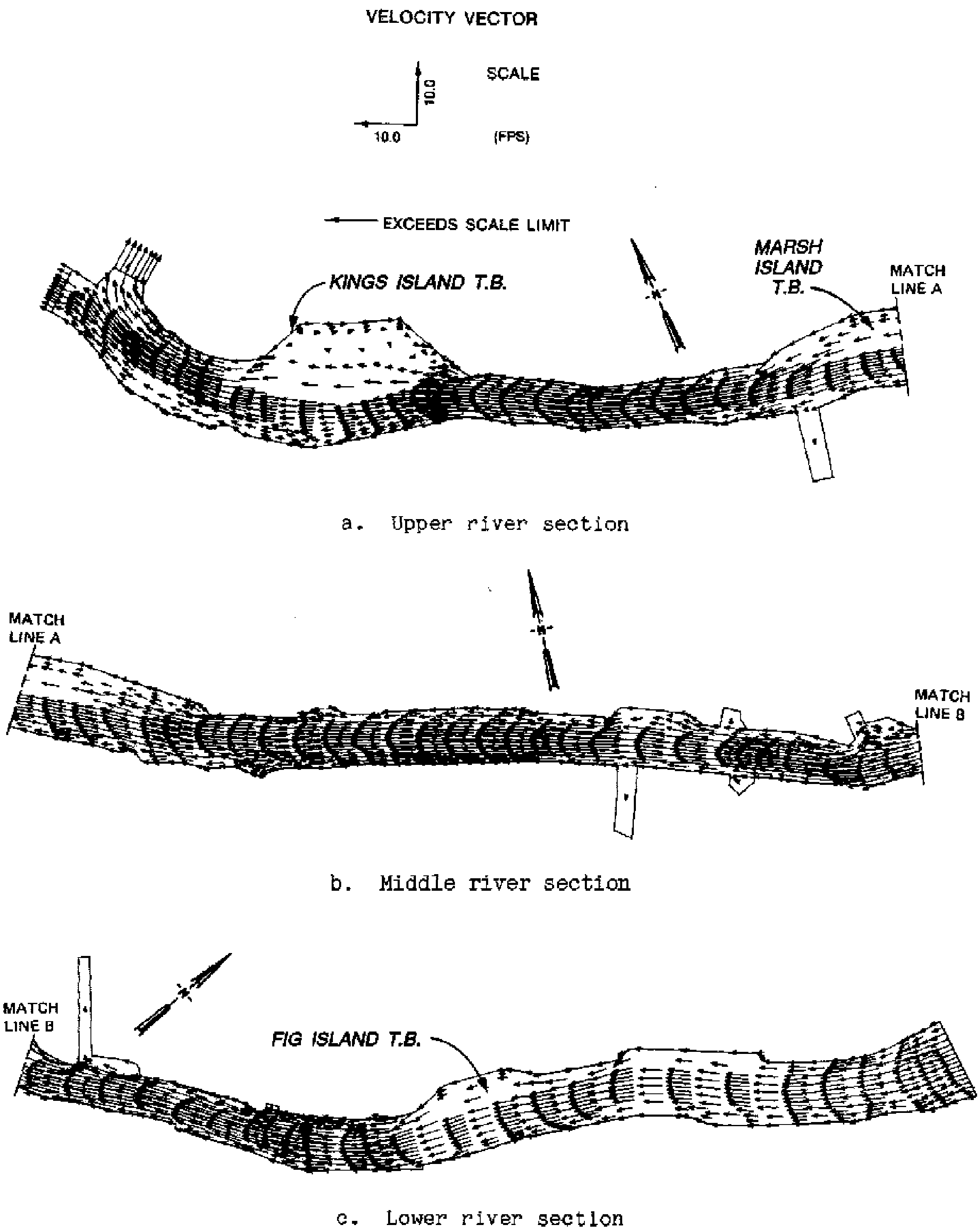


Figure C-11. Maximum flood velocities, existing channel, 10.5-foot tidal range

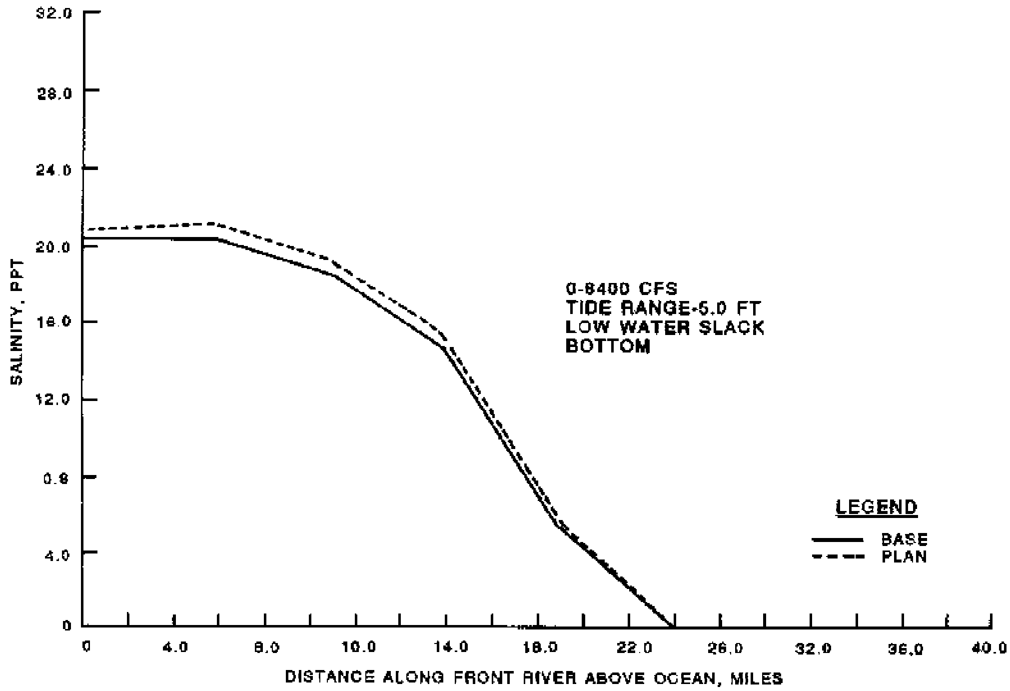


Figure C-12. Salinity change predicted by LAEMSED model

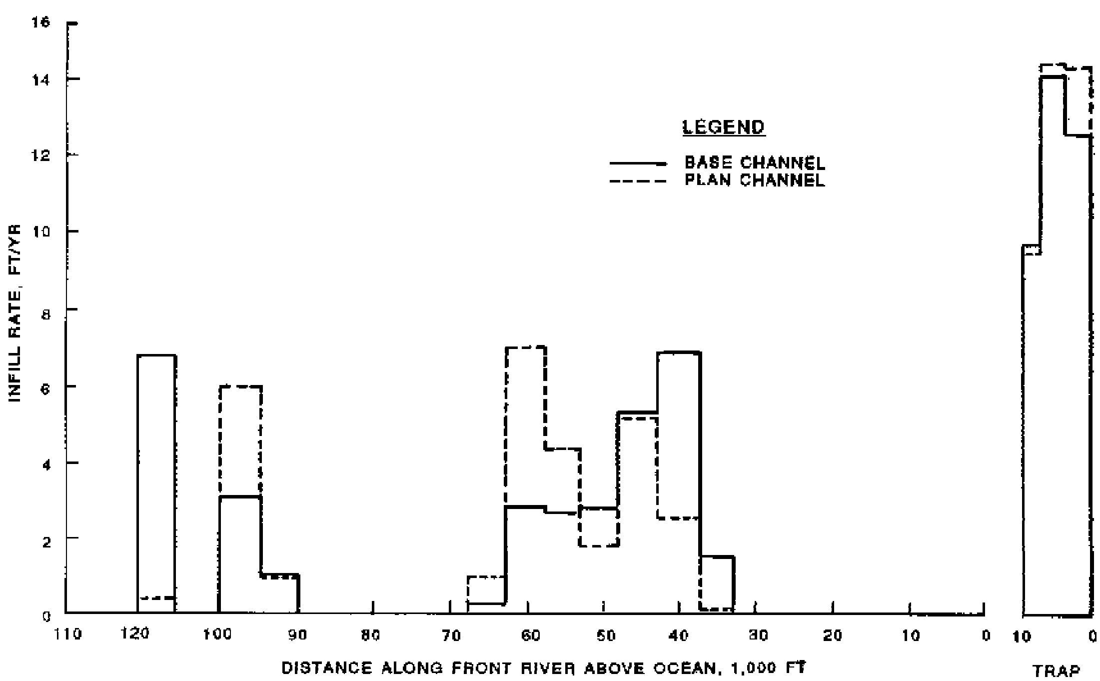


Figure C-13. Comparison of base and plan shoaling

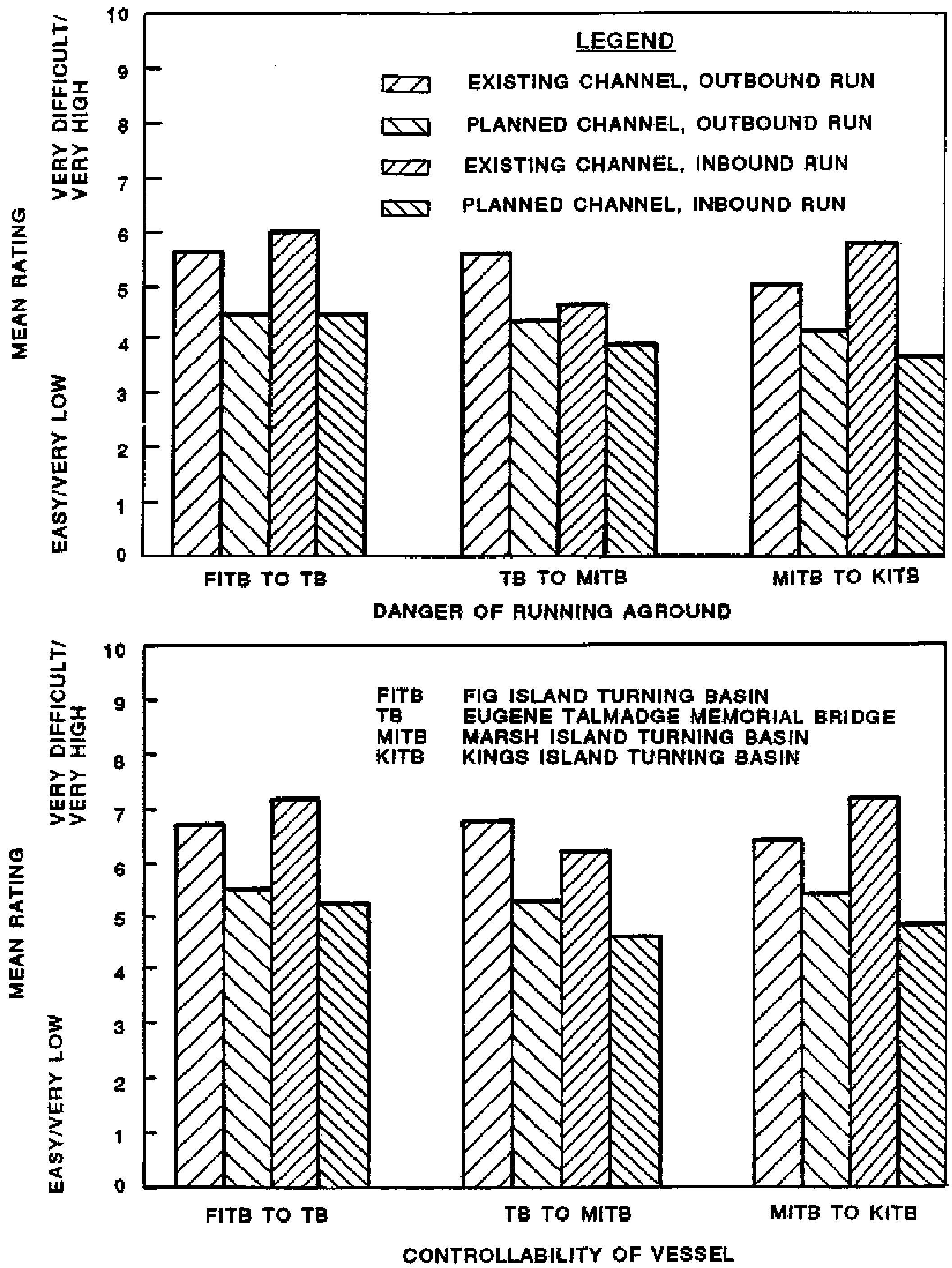


Figure C-14. Typical results from the ship simulator study